EFFECTIVENESS OF BUS PRIORITY AT MOVA CONTROLLED TRAFFIC SIGNALS

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Introduction

The concern over the dangers of air pollution continues to increase, as does the level of encouragement for using public transport. However, local authority budgets continue to decline and their ability to provide physical infrastructure for public service vehicles has diminished. This has led to the development of technology-driven solutions that allow buses to be prioritised through traffic signal-controlled junctions.

Recent technological advances in the MOVA M8 traffic signal control system have enabled select vehicles to be specifically considered during the signal timing optimisation process. Using the modelling packages for traffic microsimulation, PTV Vissim and TRL PCMOVA3, this paper summarises an MSc research dissertation and investigates the efficacy of having a weighted degree of priority for buses over several signalled junctions. Different weighting factors have been tested using competing priority combinations, demonstrating that bus priority can lead to reduced bus journey times by up to 15.4%. It is also shown that this can lead to improvements in overall performance of the network, reducing overall delay by up to 14%, therefore, providing significant benefits to all users.

Test Sites

Due to the number of variations in junction type available, it was decided that three hypothetical junctions would be modelled in total.

Firstly, a simple two-stage operation junction was first decided upon to evaluate the effects of bus priority. Secondly, a three-stage junction with an opposed right turn movement, and thirdly, a more complex five-stage junction, utilising the 6MRR feature in MOVA.

Buses accounted for 5% of the overall traffic and detectors were placed at approximately 12 seconds cruise time away on an approach and assigned a priority MOVA detector. Each priority link was also coupled with a cancel detector to prevent any further priority actions once a bus had crossed the stop line.

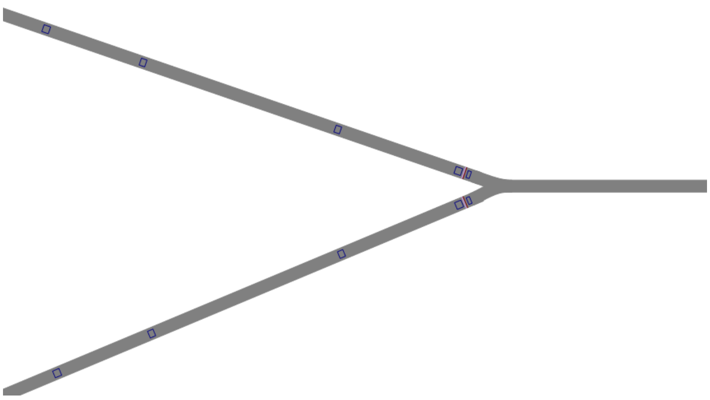

Figure 1 - Test Site 1 Vissim Model Layout

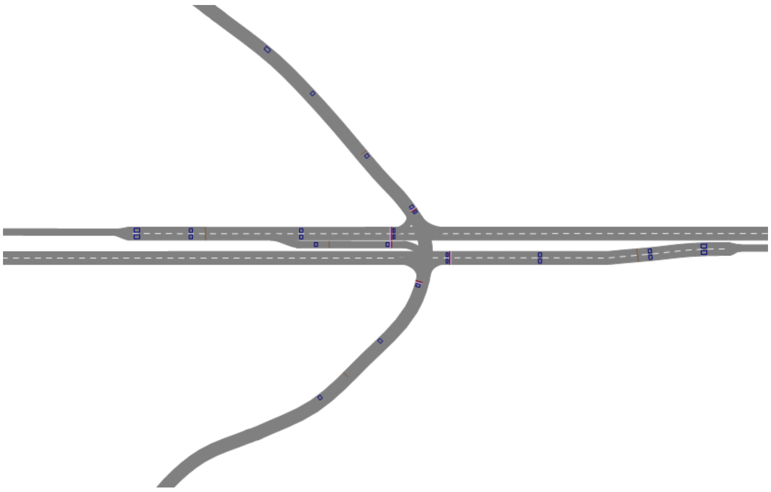

Figure 2 - Test Site 2 Vissim Model Layout

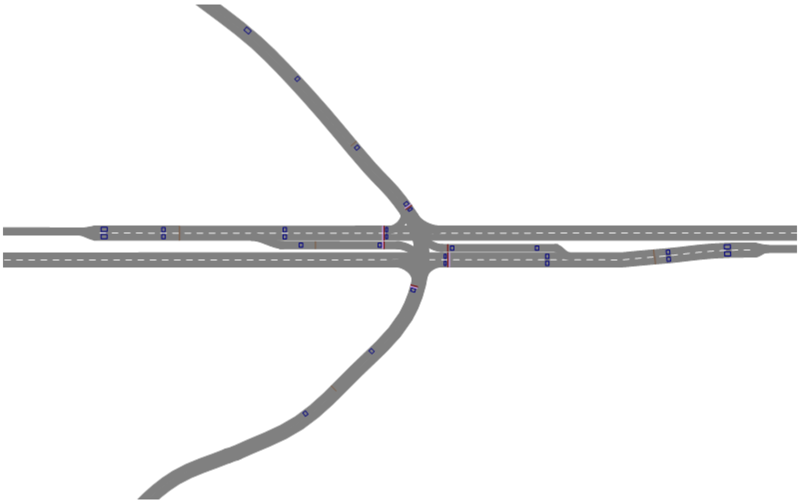

Figure 3 - Test Site 3 Vissim Model Layout

For test Sites 2 and 3, bus priority was applied to the main road approaches and the northern arm of the junctions. The following tables summarise the different scenarios of competing priority that were tested at each site.

Table 1 shows the different priority combinations tested and the number of Vissim modelling runs for Test Site 1.

Table 1 - Test Site 1 Scenario Matrix

Scenario / Bus Weighting Factor	0	2000	4000	6000	8000	10000
Priority solely on Approach A	20	20	20	20	20	20
Competing Priority on Approach A & B	20	20	20	20	20	20

Table 2 shows the different priority combinations tested and the number of Vissim modelling runs for Test Site 2.

Table 2 - Test Site 2 Scenario Matrix

Scenario / Bus Weighting Factor	0	2000	4000	6000	8000	10000
Priority on Eastbound and Westbound Approaches	20	20	20	20	20	20
Priority solely on Southbound Approach	20	20	20	20	20	20
Competing Priority on Eastbound, Westbound & Southbound Approaches	20	20	20	20	20	20

Table 3 shows the different priority combinations tested and the number of Vissim modelling runs for Test Site 3.

Table 3 - Test Site 3 Scenario Matrix

Scenario / Bus Weighting Factor	0	2000	4000	6000	8000	10000
Priority on Eastbound and Westbound Approaches	20	20	20	20	20	20
Priority solely on Southbound Approach	20	20	20	20	20	20
Competing Priority on Eastbound, Westbound & Southbound Approaches	20	20	20	20	20	20

Each model was set up to record bus journey time data on each approach to the intersection, along with network performance figures. Data was gathered in 5-minute intervals for a 90-minute model run. The 15-minute warmup and cool down periods were removed, allowing 12 time periods to be analysed per run, equating to a sample size of 240 time periods across 20 simulation runs.

To ascertain the validity of the data, each analysis set was checked with a 95% confidence interval and compared with the standard deviation. Due to the large sample set, it has been assumed that the data is normally distributed.

Results

The following tables summarise the results from each test site.

Test Site 1

Table 4 - Test Site 1 Bus Journey Time Results Summary

Bus Weighting Factor	Priority on Approach A (Approach A)		Priority on Approach A (Approach B)		Equal Priority (Approach A)		Equal Priority (Approach B)	
	Average Journey Time (s)	% Saving	Average Journey Time (s)	% Saving	Average Journey Time (s)	% Saving	Average Journey Time (s)	% Saving
0	30.8		31.2		30.8		31.2	
2000	26.5	14.0%	31.4	-0.8%	26.9	12.9%	26.4	15.4%
4000	26.5	14.0%	31.4	-0.8%	26.8	13.0%	26.6	14.7%
6000	26.5	14.0%	31.4	-0.8%	26.4	14.5%	27.4	12.3%
8000	26.5	14.0%	31.4	-0.8%	26.4	14.2%	26.9	13.7%
10000	26.5	14.0%	31.4	-0.8%	26.6	13.9%	26.9	13.7%

Table 5 - Test Site 1 Network Delay Results Summary

Bus Weighting Factor	Approach A Priority		Equal Priority	
	Network Delay (s)	% Saving	Network Delay (s)	% Saving
0	2024.33		2024.332	
2000	1880.23	7.1%	1743.088	13.9%
4000	1880.23	7.1%	1765.64	12.8%
6000	1880.23	7.1%	1776.883	12.2%
8000	1880.23	7.1%	1775.64	12.3%
10000	1880.23	7.1%	1775.541	12.3%

Test Site 2

*Table 6 – Test Site 2 **Eastbound** Bus Journey Times Results Summary*

Bus Weighting Factor	Main Road Priority		Side Road Priority		Equal Priority	
	Average Journey Time (s)	% Saving	Average Journey Time (s)	% Saving	Average Journey Time (s)	% Saving
0	28.0		28.0		28.0	
2000	26.0	7.2%	28.8	-2.8%	27.5	1.8%
4000	26.2	6.3%	28.7	-2.6%	26.9	4.2%
6000	26.2	6.4%	28.8	-2.8%	26.7	4.7%
8000	26.2	6.2%	28.8	-2.8%	27.3	2.5%
10000	26.2	6.2%	28.8	-2.8%	27.2	3.0%

*Table 7 - Test Site 2 **Westbound** Bus Journey Times Results Summary*

Bus Weighting Factor	Main Road Priority		Side Road Priority		Equal Priority	
	Average Journey Time (s)	% Saving	Average Journey Time (s)	% Saving	Average Journey Time (s)	% Saving
0	37.2		37.2		37.2	
2000	34.2	8.0%	38.1	-2.5%	34.3	8.2%
4000	34.1	8.2%	38.2	-2.6%	35.4	4.9%
6000	34.4	7.5%	38.1	-2.6%	35.2	5.6%
8000	34.3	7.7%	38.1	-2.6%	35.7	4.2%
10000	34.3	7.7%	38.1	-2.5%	35.8	3.7%

*Table 8 - Test Site 3 **Southbound** Bus Journey Time Results Summary*

Bus Weighting Factor	Main Road Priority		Side Road Priority		Equal Priority	
	Average Journey Time (s)	% Saving	Average Journey Time (s)	% Saving	Average Journey Time (s)	% Saving
0	39.4		39.4		39.4	
2000	44.0	-10.4%	39.1	0.7%	40.8	-3.6%
4000	43.8	-10.0%	39.5	-0.2%	40.4	-2.5%
6000	44.4	-11.4%	39.3	0.2%	39.9	-1.4%
8000	44.5	-11.5%	39.3	0.2%	40.2	-2.0%
10000	44.5	-11.5%	39.3	0.1%	40.0	-1.7%

*Table 9 - Test Site 2 **Network Delay** Summary Results*

Bus Weighting Factor	Main Road Priority		Side Road Priority		Equal Priority	
	Network Delay (s)	% Saving	Network Delay (s)	% Saving	Network Delay (s)	% Saving
0	4948.8		4948.81		4948.81	
2000	4867.7	1.6%	5001.27	-1.0%	4869.83	1.6%
4000	4862.9	1.7%	4986.11	-0.7%	4888.55	1.2%
6000	4861.4	1.8%	4982.92	-0.7%	4890.88	1.2%
8000	4864.9	1.7%	4983.05	-0.7%	4888.56	1.2%
10000	4864.9	1.7%	4983.66	-0.7%	4883.64	1.3%

Test Site 3

*Table 10 - Test Site 3 **Eastbound** Bus Journey Times Results Summary*

Bus Weighting Factor	Main Road Priority		Side Road Priority		Equal Priority	
	Average Journey Time (s)	% Saving	Average Journey Time (s)	% Saving	Average Journey Time (s)	% Saving
0	43.1		43.1		43.1	
2000	40.4	6.5%	43.7	-1.2%	40.7	5.6%
4000	40.4	6.4%	44.2	-2.4%	41.6	3.6%
6000	40.1	7.1%	44.5	-3.0%	41.4	4.0%
8000	39.9	7.5%	44.4	-2.9%	41.8	3.0%
10000	39.9	7.5%	44.2	-2.3%	42.0	2.8%

*Table 11 - Test Site 3 **Westbound** Bus Journey Time Results Summary*

Bus Weighting Factor	Main Road Priority		Side Road Priority		Equal Priority	
	Average Journey Time (s)	% Saving	Average Journey Time (s)	% Saving	Average Journey Time (s)	% Saving
0	42.5		42.5		42.5	
2000	39.5	7.0%	43.3	-1.8%	40.8	4.0%
4000	40.1	5.5%	43.1	-1.5%	40.7	4.1%
6000	39.9	6.1%	43.4	-2.2%	40.8	4.0%
8000	39.8	6.3%	43.6	-2.7%	41.3	2.7%
10000	39.8	6.3%	43.4	-2.3%	41.9	1.3%

*Table 12 - Test Site 3 **Southbound** Bus Journey Time Results Summary*

Bus Weighting Factor	Main Road Priority		Side Road Priority		Equal Priority	
	Average Journey Time (s)	% Saving	Average Journey Time (s)	% Saving	Average Journey Time (s)	% Saving
0	45.9		45.9		45.9	
2000	49.0	-6.3%	45.8	0.3%	47.0	-2.3%
4000	48.8	-6.0%	43.1	6.2%	45.2	1.5%
6000	48.1	-4.6%	43.7	4.8%	46.3	-0.8%
8000	47.9	-4.2%	43.7	4.8%	46.6	-1.5%
10000	47.9	-4.2%	43.6	4.9%	45.7	0.4%

*Table 13 - Test Site 3 **Network Delay** Summary Results*

Bus Weighting Factor	Main Road Priority		Side Road Priority		Equal Priority	
	Network Delay (s)	% Saving	Network Delay (s)	% Saving	Network Delay (s)	% Saving
0	8924.9		8924.9		8924.9	
2000	8638.1	3.2%	9043.5	-1.3%	8569.9	4.0%
4000	8544.2	4.3%	9050.5	-1.4%	8731.5	2.2%
6000	8609.7	3.5%	9073.8	-1.6%	8619.2	3.4%
8000	8630.6	3.3%	9058.0	-1.5%	8816.8	1.2%
10000	8630.6	3.3%	8994.4	-0.8%	8740.5	2.1%

Discussion

Test Site 1 data showed that there were initial benefits for the use of a bus weighting factor, but subsequently there were little or no changes in travel times or junction delay when weighting increased. This was unexpected but could be due to the simplicity of the site, and in this scenario, bus priority is simply either on or off, making the weighting factor redundant. Therefore, increasing bus priority beyond the lowest weighting was not beneficial.

In addition, Test Sites 2 and 3 showed similar trends, which resulted in an initial improvement with few subsequent fluctuations in results, showing no linear correlation. This may suggest that the weighting factors used were too generous, as the lowest value tested (2000) often showed the most benefit at all sites. Also, as the weighting factor increased, there were few significant changes in the results, which may be due to random arrival patterns forming queues. It is, therefore, possible that greater benefits can be achieved by applying a weighting factor of less than 2000. The results show that this modest level of priority, however, is enough to influence the optimisation process without too much interference with the traffic model to have a negative impact. Furthermore, the findings show that disrupting internal traffic models of optimisers may have a negative impact on performance; suggesting that, as the weighting factor increases, buses are essentially given absolute priority. Additionally, Test Site 2 & 3 showed that there were advantages to bus journey times and network delays when a factor of between 4000 and 6000 was applied on the main road. Therefore, suggesting that the conditional prioritisation of buses with a high schedule deviation may lead to a higher level of punctuality, without adversely affecting junction performance.

Test Site 1 produced the most significant benefits, with bus journey times reduced by 15.4% and network delays reduced by 14%. This could be due to the simplicity of signal staging affecting the future red-time calculation and allowing the optimisation process to be extended longer; thus, increasing the likelihood that the approaching bus will pass through the already existing green signal.

Test Site 2, on the other hand, indicated that the use of bus priority solely on the side road had a negligible impact on bus journey times but caused a reduction in junction performance. This decline in performance is likely due to the MOVA algorithm itself, whereby extensions to the green on less dominant approaches actively cleared the queue on a single cycle but resulted in an increased queue length at the busier approaches. Furthermore, once the busier approaches were green, a significant amount of time was required for MOVA to detect the end of the saturation flow (to allow the optimisation process to take place), which increased the delay on the side road. Moreover, when the side road was green, the decision to end the stage was made quickly once the end of the saturation flow had been detected, without any periods of extended optimisation. It appeared that the benefit of ending the stage immediately outweighed the benefit of extending it when there were heavy conflicting traffic flows.

At Test Site 3, side road journey times decreased by approximately 6% before levelling off as the weighting factor increased. The reason for this is unclear but could be attributed to the more complex staging arrangement increasing the lost time per cycle; whereby the stops and delays optimisation process is shortened, and the side road was served quicker. However, despite improvements to the side road, the benefits were not as great as those gained by the main road traffic, which is possibly due to the speed at which the queue builds if the vehicles are stopped. As a result, the reliability of bus journey times was much more sensitive to an approach with more traffic, thus seeing the greatest benefit of prioritisation.

All three sites have shown that it is possible to reduce the overall delay in a junction by applying a weighting factor to buses. It can be inferred that this was due to several reasons; buses have a slower rate of acceleration than cars, therefore, if a bus stops at a set of signals, the following vehicles will also suffer additional delays as the bus starts to move, compared to a queue of cars only. If the bus passes through the signals, there will be less delay in the subsequent start of the vehicles. Another explanation for the overall delay reduction is the number of additional vehicles passing through the junction as the signals remain green for the bus. Either the vehicles that precede the bus will drive through the signals where they would have stopped before, or the additional group will pass through after the bus, as they further affect the optimisation process.

It should be noted that the application of the bus priority to the main road in Test Site 2 & 3 provided the greatest overall delay reduction for these sites. However, applying bus priority equally across all competing approaches produced very similar delay results, while providing travel time benefits for all approaches. The prioritisation of buses in this way will likely be far more acceptable politically than that only of the main road.

Each scenario tested shows that bus priority in MOVA is an effective way of reducing bus delays and improving overall junction performance. The costs of implementing the MOVA bus priority are likely to be negligible compared to physical infrastructure projects and should, therefore, be considered at all isolated junctions where a significant number of bus services pass through. These measures have the potential to improve air quality, increase the reliability of services and increase bus patronage.

Recommendations

Trends show that increasing the weighting factor excessively can lead to a levelling or deterioration of bus journey times and a reduction in overall junction performance. This could potentially be accounted for by noisy data, making it difficult to recommend the use of higher weighting values. However, substantial improvements can be seen when applying the equal weighting factor of 2000 over all approaches, indicating that this is a reasonable starting point for on-site implementation.

Recognising the limitations of this research, it would be prudent to further investigate different junction layouts and flow levels. This research found that there is a consistent improvement once the bus weighting factor of 2000 was applied, but the impacts of the weighting factors between 0–2000 have not yet been investigated.

Another area of further investigation is the alternative locations of SVD's and how their position may affect the optimisation process. It is assumed that increasing the distance away from the junction would lead to a further reduction in the bus delay.

A full copy of the dissertation is available upon request.

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